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(54) **Peroxide vulcanized rubber composition**

Mit Peroxiden vulkanisierte Kautschukmischungen

Composition de caoutchouc vulcanisé à l'aide de peroxydes

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(56) References cited:
EP-A- 0 346 863 **FR-A- 1 257 913**
US-A- 2 925 407

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Description

This invention relates to a rubber composition having improved physical properties. More particularly, it relates to a peroxide-vulcanized rubber composition which is vulcanized in the presence of a bisimido compound and a radical scavenger to control the scorch time.

It is essential with the injection moulding and continuous vulcanization of rubber articles that the mouldable rubber in the extruder and in the conveyor to the mould remain processable, i.e. readily flowable, as long as possible. In the mould, however, the rubber should crosslink as rapidly as possible. Faster crosslinking permits a higher rate of production.

Since the viscosity of the mouldable rubber decreases with higher temperatures, it is desirable to maintain the temperature in the extruder and the conveyor to the mould as high as possible without risking premature crosslinking. In practice, the maximum processing temperature in the extruder/conveyor is at least 30° to 50°C below the temperature in the mould (vulcanization temperature). A small increase in the processing temperature and/or extension of the residence time in the extruder/conveyor can, above a certain critical level (or threshold-value), lead to premature crosslinking, which is characterized by wrinkled or "scorched" spots on the smooth surface of the rubber article produced. This phenomenon is commonly known as "scorch".

The tendency of a rubber to scorch under commercial operating conditions may be measured by means of an oscillating disc curemeter, which procedure is described in International Standard ISO 3417. A test piece of rubber is maintained at an elevated temperature. A biconical disc is embedded in the test piece and is oscillated. This action exerts a shear strain on the test piece and the force (torque) required to oscillate the disc depends on the degree of vulcanization of the rubber at the elevated temperature at a certain time. The torque is recorded as a function of time.

Indicative of the scorch time of a rubber is the t_{s2} value, which is the time for the torque to increase 0.1 Nm above the minimum torque, measured in the curemeter. Indicative of the necessary residence time in the mould is the t_{90} value (vulcanization time), which is the time required to obtain 90% of full torque development. The higher the t_{90} value, the longer the residence time in the mould. The final properties of the rubber article depend, to a significant extent, on the crosslink density (degree of crosslinking). Indicative of the crosslink density is the highest torque measured in the curemeter. Another way of measuring the above-mentioned values is described in International Standard ISO 6502.

Until now, the scorching problem has been solved at the expense of either a significantly longer production time (t_{90}) or an undesirable worsening of the properties of the rubber compositions. For example, typical antioxidants can be used to lengthen the scorch time but invariably lead to a significantly lower crosslink density in the rubber product. It is also possible to extend the scorch time by, for example, adding initiators which have a longer half-life period. Such alternative, however, also results in a longer crosslinking period and hence an undesired lowering of the production rate. Combinations of some coagents with antioxidants have been tried, but all have one or more disadvantages in either compression set, crosslink density or production time.

EP 0 346 863 describes polymer compositions containing an organic peroxide, a hydroquinone derivative, and a coagent such as triallyl cyanurate to extend the scorch time (t_{s2}).

US 4 857 571 describes a crosslinkable rubber to which a peroxide, a coagent, such as acrylate, methacrylate, or triallyl cyanurate, and a special scorch retardant containing a phenol group and an amino group, have been added.

FR 1 259 094 describes the use of bismaleimides and biscitraconimides in the vulcanization of saturated polymers in the presence of organic peroxides. Although it is possible to add other vulcanization agents no details are given. Furthermore, this publication does not teach or suggest the process of the present invention nor the advantages which flow therefrom.

In CA 738 500 rubber vulcanization processes are disclosed wherein bismaleimides and biscitraconimides are employed as vulcanization agents in the absence of free radical initiators, optionally in the presence of thiazole type accelerators. The rubbers obtained by this process are said to have a better resistance to oxidative aging than sulfur-vulcanized rubbers. In addition, rubber stocks containing the bismaleimides and biscitraconimides are usable in the presence of metals which are normally tarnished by those stocks and can be processed at higher temperatures than sulfur-containing rubber stocks without scorching. CA 738 500 also discloses a process for the vulcanization of polyurethane rubbers using a bismaleimide or biscitraconimide curing agent and a free radical initiator. Polyurethane rubber vulcanizates cured in this manner exhibit a higher tear strength, better resistance to aging and a higher tensile strength at high temperature. Although this Canadian patent mentions that antioxidants may be used in the vulcanization processes, no specific details are given. Further, this patent does not teach or suggest the process of the present invention or the advantages which flow therefrom.

US 4 018 852 relates to crosslinkable polyethylene compositions comprising an organic peroxide, an organic hydroperoxide and a triallyl compound. This patent provides a detailed discussion of the desirability of reducing scorching by extending the scorch time, as well as the desirability to maintain a relatively short production time and good physical properties in the rubber product.

The present approach to achieve long scorch times in peroxide vulcanization is to have the highest possible $t_{s2}:t_{90}$

ratio (scorch ratio), without any of the other physical properties of the rubber being significantly altered.

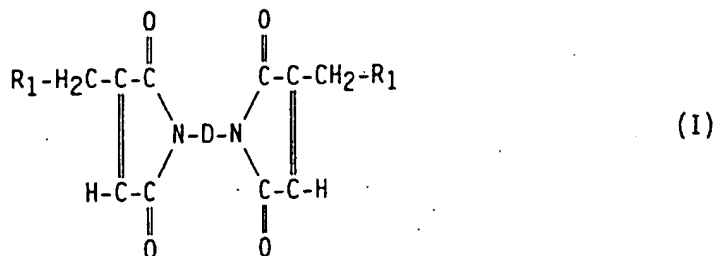
Accordingly, it remains desirable to lengthen the scorch time in peroxide rubber vulcanization processes without significantly lengthening production time or negatively influencing the advantageous properties of the rubber product.

The present invention provides a solution to the above problems by the use of a combination of a bisimido compound of the formula I and a radical scavenger in the peroxide-vulcanization of rubbers. More particularly, the present invention relates to a peroxide-vulcanized rubber composition which comprises the vulcanization reaction product of:

(A) 100 parts of at least one natural or synthetic rubber;

(B) 0.04 to 10 parts by weight of an organic peroxide;

(C) 0.5 to 10 parts by weight of a bisimido compound represented by formula I:



wherein D is a divalent group chosen from the group of alkylene, alkarylene, cycloalkylene, arylen, aralkylene, and alkenylene, and R is hydrogen or an alkyl group with 1-18 carbon atoms; and

(D) 0.1 to 10 parts by weight of a radical scavenger,

all amounts being based on the weight of said rubber.

In addition, the present invention relates to a vulcanization process carried out in the presence of the bisimido compounds of the formula I and a radical scavenger and the use of the combination of a bisimido compound of the formula I and a radical scavenger to control scorch time in the peroxide-vulcanization of rubbers.

The present invention provides the ability to achieve, during vulcanization, a long scorch time without the crosslink density and the crosslinking time (t_{90}) being adversely affected. Furthermore, the invention also provides improved rubber compositions.

The present invention is applicable to all natural and synthetic rubbers. Examples of such rubbers include, but are not limited to, natural rubber (NR), ethylene-propylene-dienemonomer terpolymers (EPDM), styrene-butadiene rubber (SBR), acrylonitrile-butadiene rubber (NBR), hydrogenated acrylonitrile-butadiene rubber (HNBR), polyisoprene rubber (IR), acrylonitrile-butadiene-styrene terpolymers (ABS), styrene-butadiene-styrene rubber (SBS), styrene-isoprene-styrene rubber (SIS), polychloroprene rubber (CR), poly-butadiene, halogenated isoprene-isobutylene rubber (BIIR or CI-IR), ethylene-propylene copolymers (EPM), ethylene-vinylacetate copolymers (EVA), chloro polyethylene (CM/CPE), chlorosulfonyl polyethylene (CSM), high density polyethylene (HDPE), low density polyethylene (LDPE, LLDPE), silicone rubber, as well as combinations of two or more of these rubbers and combinations of one or more of these rubbers with other rubbers and/or thermoplastics.

Examples of organic peroxides which may be used in the present invention are di-tert-butyl peroxide, tert-butyl cumyl peroxide, bis(tert-butylperoxyisopropyl)benzene, dicumyl peroxide, butyl 4,4-bis(tert-butylperoxy)valerate, 2,5-bis(tert-butylperoxy)-2,5-dimethylhexane, 2,5-bis(tert-butylperoxy)-2,5-dimethyl-3-hexyne, tert-butyl 3-isopropenylcumyl peroxide, bis(3-isopropenylcumyl) peroxide, 1,1-bis(tert-butylperoxy)-3,3,5-trimethylcyclohexane, tert-butyl peroxybenzoate, dibenzoyl peroxide, and bis(2,4-dichlorobenzoyl) peroxide. Combinations of organic peroxides can also be used. Preferably, 1,1-bis(tert-butylperoxy)-3,3,5-trimethylcyclohexane, bis(tert-butylperoxyisopropyl)benzene, and tert-butyl 3-isopropenylcumyl peroxide are used as organic peroxides.

Biscitraconimido compounds are known and can be prepared by the methods disclosed in, "The Synthesis of Biscitraconimides and Polybiscitraconimides," Galanti, A.V. and Scola, D.A., Journ. of Poly. Sci.: Polymer Chemistry Edition, Vol. 19, pp. 451-475, (1981), the disclosure of which is hereby incorporated by reference. "The Synthesis of Bisitaconamic Acids and Isomeric Bisimide Monomers," Galanti, A.V. et al., Journ. Poly. Sci.: Polymer Chemistry Edition, Vol. 20, pp. 233-239 (1982) also discloses a method for the preparation of biscitraconimido compounds in the form of an isomeric mixture of the citraconic and itaconic imides, the disclosure of which is also hereby incorporated by reference.

The more preferred bisimido compounds of the present invention represented by the formula I include, but are not

limited to, the bisimido compounds wherein D is chosen from the group of C₁₋₁₈-alkylene, C₇₋₃₀-alkarylene, C₃₋₁₈-cycloalkylene, C₆₋₃₀ arylene, C₇₋₃₀-aralkylene, and C₂₋₁₈-alkenylene and R₁ is hydrogen or a C₁₋₁₈-alkyl group. More preferably, R₁ is hydrogen.

More specific examples of some of the bisimido compounds useful in the invention, include but are not limited to the following:

1,2-N,N'-dimethylene-biscitraconimide;
1,2-N,N'-trimethylene-biscitraconimide;
1,5-N,N'-(2-methyl-pentamethylene)-biscitraconimide; and
N,N'-meta-phenylene-biscitraconimide.

Examples of radical scavengers include but are not limited to antioxidants and mercapto derivatives. Any typical antioxidant for rubber vulcanization may be employed. Preferably, a phenolic antioxidant is used. More specific examples of some phenolic antioxidants are: 2,6-bis(tert-butyl)-4-methylphenol, bis(2-hydroxy-5-methyl-3-(1-methylcyclohexyl)phenyl)methane, 2,5-bis(tert-amyl)hydroquinone, tert-butylhydroquinone and 2,6-bis(tert-butyl)-4-dimethylaminomethylphenol. As mercapto derivative dibenzothiazyl disulfide is preferred.

The amount of organic peroxide, based on 100 parts rubber, is 0.04-10 parts by weight, preferably 1-4 parts by weight. The amount of bisimido compound in the vulcanizable rubber composition is 0.5 to 10 parts by weight, preferably 1-4 parts by weight. The amount of radical scavenger added to the composition is 0.1-10 parts by weight, preferably 0.1-4 parts by weight.

Other conventional rubber additives may also be employed in their usual amounts. For example, reinforcing agents such as carbon black, silica, clay, chalk and calcium carbonate may be included in the rubber composition. Other additives such as tackifiers, waxes, further antioxidants, pigments, UV-stabilization agents, antiozonants, blowing agents, extender oils, like paraffinic oils, may also be included alone or in combination.

The present invention also relates to the vulcanization of a vulcanizable rubber composition containing a natural or a synthetic rubber with 0.04 to 10 parts by weight per 100 parts rubber, of an organic peroxide, comprising the step of vulcanizing said rubber at a temperature of from 80 to 300°C for a period of 30 seconds up to 10 hours to crosslink the rubber composition, characterized in that said vulcanizable rubber composition further comprises 0.5 to 10 parts by weight of a bisimido compound represented by formula I and 0.1 to 10 parts by weight of a radical scavenger, all amounts being based on 100 parts by weight of said rubber.

All of the additives mentioned above with respect to the rubber composition may also be present during the vulcanization process of the invention.

preferably, the process is carried out at 120-180 °C for a period of 2 minutes up to 2 hours. The processing temperature, i.e. the temperature during extrusion and conveying, ranges from 50 to 150 °C. To carry out the process according to the invention known techniques and machines can be used.

The present invention also comprises the use of the combination of a bisimido compound of formula I and a radical scavenger to control scorch time in the peroxide-vulcanization of rubber.

The invention is further illustrated by the following examples which are not to be construed as limiting the invention in any way. The scope of the invention is to be determined from the claims appended hereto.

Materials

Materials will be added to the process in parts per hundred based on the rubber (phr).

Rubbers:	Ethylene propylene diene monomer (EPDM: third monomer is cyclopentadiene) Ethylene vinylacetate (EVA)
Extender oil:	paraffinic oil
Peroxide:	bis(tert-butylperoxyisopropyl)benzene
Coagents:	triallyl cyanurate ("TAG") ethylene glycol dimethacrylate ("EDMA") N,N'-meta-phenylene-bismaleimide ("HVA-2") Triallyl trimellitate ("TATM") 1,2-N,N'-dimethylene-bis(dimethyl)maleimide ("BOMM-C2") 1,2-N,N'-dimethylene-biscitraconimide ("BCI-C2") 1,2-N,N'-trimethylene-biscitraconimide ("BCI-C3") 1,5-N,N'-(2-methyl-pentamethylene)-biscitraconimide ("BCI-C6") N,N'-meta-phenylene-biscitraconimide ("BCI-MP")
Radical scavengers:	2,6-bis(tert-butyl)-4-methylphenol ("BHT")

tert-Butylhydroquinone ("TBHQ")
 2,5-bis(tert-amyl)hydroquinone ("DAHQ")
 bis(2-hydroxy-5-methyl-3-(1-methylcyclohexyl)phenyl) methane ("WSP")
 2,6-bis(tert-butyl)-4-dimethylaminomethyl phenol ("E703")
 polymerised 2,2,4-trimethyl-1,2-dihydroquinoline ("TQ") dibenzothiazyl disulphide ("MBTS")

Measuring of the rheological properties

(unless mentioned otherwise)

The rheological behaviour of the rubber compositions was measured on a Monsanto rheometer TM-100 ODR, micro die (180 °C: 30 minutes/ range 10 N.m/ arc=3°). The rheological behaviour gives an indication of the scorch time, the vulcanization time and the crosslink density in the rubber (International Standard ISO 3417).

Measuring of the mechanical properties

For the mechanical tests the rubber compositions were crosslinked under pressure at 150°C during 15 minutes. Moduli were measured according to International Standard ISO 37/2 Dumb-bell.

Tear- and tensile-strength were determined on a Zwick-1445 tensile tester according to International Standards ISO 37/2-Db en 34/2-Db, respectively.

The compression set was determined at 100°C during 72 hours according to International Standard ISO R-815. The IRHD-hardness was determined according to International Standard ISO 48.

The rubber compositions were aged in a hot-air oven at 100-120°C during 168 hours and subsequently stored overnight at room temperature.

Examples 1-8 and Comparative Examples A-B

100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil were mixed over 5 minutes in a 1-liter Banbury-mixer at 120°C.

4.2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene and different amounts of BHT and BCI-C2 were added to the rubber mixture on a two-roll mill (friction ratio 1:1.2) over 5 minutes at 40 °C.

The results of the rheological measurements during the vulcanization at 180°C are listed in Table 1.

TABLE 1

Ex. no.	BCI-C2 (phr)	BHT (phr)	t _{s2} (min.)	t ₉₀ (min.)	t _{s2} /t ₉₀	Δtorque (N.m)
control	-----	---	1.06	8.48	0.125	7.12
A	1	---	1.07	8.20	0.13	9.54
B	4	---	1.16	7.70	0.15	11.54
1	1	0.9	1.29	8.06	0.16	8.18
2	1	1.75	1.34	8.38	0.16	7.14
3	1	3.5	1.58	8.30	0.19	5.91
4	2	1.75	1.46	7.70	0.19	8.08
5	2	3.5	1.69	7.50	0.225	7.12
6	3	1.75	1.49	7.25	0.205	8.77
7	3	3.5	1.52	8.01	0.19	7.91
8	4	3.5	1.73	8.88	0.195	7.81

t₉₀: vulcanization time

Δtorque: measure of crosslink density

The results show that processes where to a biscitraconimido compound is added but no antioxidant (Comparative Examples A and B) do not show a remarkable difference in scorch time as compared to the control to which no coagent and no antioxidant is added. The crosslink density of the crosslinked rubber, however, is drastically increased. The addition of BHT to the rubber compositions improves the scorch ratio compared to Comparative Examples A and B during the vulcanization, while the vulcanization time and the crosslink density of the crosslinked rubber have not significantly changed with respect to the control rubber.

Example 9 and Comparative Examples C-D

100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil were mixed over 5 minutes in a 1-liter Banbury-mixer at 120 °C. 4.2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, TBHQ and coagents were added to this rubber mixture on a two-roll mill (friction ratio 1:1.2) over 5 minutes at 40 °C.

The results of the rheological measurements during the vulcanization at 180 °C are listed in Table 2.

TABLE 2

Ex. no.	coagent	TBHQ (phr)	t_{s2} (min.)	t_{90} (min.)	t_{s2}/t_{90}	Δ torque (N.m)
control	-----	----	1.06	8.48	0.125	7.12
9	BCI-C2 (1 phr)	0.33	1.84	9.18	0.20	7.39
C	TAC (1 phr)	0.33	1.69	10.56	0.16	6.59
D	TATM (1.3 phr)	0.33	1.86	10.65	0.175	6.38

t_{90} : vulcanization time

Δ torque: measure of crosslink density

The results from Table 2 show that the vulcanization time and crosslink density of a rubber composition according to the invention (Example 9) are comparable to those of a rubber composition vulcanized without coagent and antioxidant (control). The scorch time and scorch ratio are, however, greatly improved by the addition of the combination of a bis-citraconimido compound and an antioxidant compared to the control. It is also clear from the results that the addition of other coagents to the rubber composition could improve the scorch time (Comparative Examples C and D). However, the vulcanization time is then too long.

Examples 10-13 and Comparative Examples E-H

A rubber mixture of 100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil was mixed on a Banbury mixer over 5 minutes at a maximum temperature of 150 °C. 2.1 phr of a 40% formulation of bis(tert-butylperoxyisopropyl) benzene, different coagents and 1.75 phr BHT were mixed over 5 minutes on a two-roll mill (friction ratio 1:1.2) at a temperature of 40-50 °C. The results of the rheological tests during vulcanization at 180°C are listed in Table 3.

TABLE. 3

Ex.no.	coagent (phr)	BHT (phr)	t _{s2} (min.)	t ₉₀ (min.)	t _{s2} /t ₉₀	Δtorque (N.m)
control	-----	----	1.36	9.7	0.14	5.0
10	BCI-C2 (1.00)	1.75	2.02	9.2	0.22	5.3
11	BCI-C3 (1.00)	1.75	1.80	9.0	0.20	5.2
12	BCI-C6 (1.20)	1.75	1.91	9.1	0.21	5.2
13	BCI-MP (1.20)	1.75	1.91	9.1	0.21	5.7
E	BDMM-C2 (1.10)	1.75	2.30	12.8	0.18	2.1
F	TAC (1.00)	1.75	2.02	11.9	0.17	4.0
G	EDMA (1.00)	1.75	2.02	10.1	0.20	4.3
H	HVA-2 (1.05)	1.75	1.33	8.3	0.16	5.9

t₉₀: vulcanization time

Δtorque: measure of crosslink density

The results from Table 3 show that the combination of BHT and biscitraconimido compounds gives longer scorch times during the vulcanization of the rubber compositions (Examples 10-13) again without disadvantages in either vulcanization time or crosslink density. The scorch time of HVA-2 (Comparative Example H) is even lower than the scorch time of the control rubber composition comprising no coagent and no antioxidant. Comparative Example E shows that a derivative structurally homologous to a biscitraconimido compound is far less efficient as a coagent than the biscitraconimido compounds. Comparative Examples F-G show that even with a good scorch time the vulcanization time can increase, slowing the production capacity. Also the crosslink density of these two Comparative Examples is worse than that of the control.

The compression set of some of the rubber compositions obtained from the previous examples, viz. 11, 13, F and G, was measured and compared to vulcanized rubber compositions where to no antioxidant was added. The results are listed in Table 4. The percentages indicate the variation between the original shape and size and the shape and size after the material is compressed and then released from compression.

Table 4

Ex.no.	coagents	no	BHT
		antioxidant	(1.75 phr)
		CS	CS
control	----	19	32
11	BCI-C3 (1 phr)	12	15
13	BCI-MP(1.2 phr)	12	16
F	TAC (1 phr)	14	22
G	EDMA (1 phr)	16	21

CS: Compression set in %

The results listed in Table 4 show that the addition of an antioxidant to a composition comprising a biscitraconimido compound increases the compression set, but, unexpectedly, not to the same extent as the increased compression set of the control rubber composition comprising no coagent. The addition of TAC or EDMA to rubber compositions provide a larger increase of compression set than the rubber compositions according to the invention.

Examples 14-16 and Comparative Example H

A rubber mixture of 100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil was mixed on a Banbury mixer at a maximum temperature of 150 °C. 2.1 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, BCI-C3 and different antioxidants were added to the rubber mixture and mixed over 5 minutes on a two-roll mill (friction ratio 1:1.2) at a temperature of 40-50°C. The rheological measurements (cure-temperature = 180 °C) are listed in Table 5. Table 6 displays the mechanical properties of the vulcanized compositions.

TABLE 5

Ex.no.	BCI-C3 (phr)	antioxidant (phr)	t _{s2} (min.)	t ₉₀ (min.)	t _{s2} /t ₉₀	Δtorque (N.m)
control	-----	-----	1.4	9.7	0.14	5.0
H	1.00	-----	1.5	8.6	0.17	6.6
14	1.00	BHT (1.75)	1.8	9.0	0.20	5.2
15	1.00	DAHQ (0.25)	1.7	10.4	0.17	4.7
16	1.00	E703 (0.5)	2.4	10.2	0.23	5.0

t₉₀: vulcanization time

Δtorque: measure of crosslink density

The results show that with the addition of a biscitraconimido compound and an antioxidant, a good scorch retardation is obtained compared with the vulcanization of the control rubber composition where to no coagent and no antioxidant are added and compared with the vulcanization of a rubber composition where to only coagent is added (Comparative Example H).

TABLE 6

Ex.no.	BCI-C3 (phr)	anti- oxidant (phr)	E100% (MPa)	E200% (MPa)	E300% (MPa)	TS (MPa)	EAB (%)
control	-----	-----	1.2	3.0	6.8	12.6	405
H	1.00	-----	1.5	4.5	---	10.2	295
14	1.00	BHT (1.75)	1.3	3.2	7.0	11.8	400
15	1.00	DAHQ (0.25)	1.2	2.8	6.2	13.3	450
16	1.00	E703 (0.5)	1.3	3.2	6.7	17.6	535

E100-300%: E-modulus at 100-300% elongation

TS: Tensile strength

EAB: Elongation at break

The control and Examples 14-15 show that the addition of antioxidant and a biscitraconimido compound gives the same mechanical properties or even improves them (Example 16: EAB). Comparative Example H shows mechanical properties which are worse in comparison with the other examples.

Examples 17-18

A rubber mixture of 100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil was mixed on a 1-liter Banbury-mixer over 5 minutes at 120 °C. 4.2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, BCI-C2 and WSP were added to the rubber mixture on a two-roll mill (friction ratio 1:1.2) over 5 minutes at 40 °C. The results of the rheological measurements during vulcanization at 180 °C are listed in Table 7.

TABLE 7

Ex.no.	BCI-C2 (phr)	WSP (phr)	t _{s2} (min)	t ₉₀ (min)	ts ₂ /t ₉₀	Δtorque (N.m)
control	-----	---	1.06	8.48	0.125	7.12
17	1	0.85	1.33	8.31	0.16	6.92
18	2	1.7	1.50	7.50	0.20	7.03

t₉₀: vulcanization time

Δtorque: measure of crosslink density

The addition of a biscitraconimido compound and WSP to rubber compositions gives a longer scorch time without significantly changing the vulcanization time or the crosslink density.

Examples 19-20

A rubber mixture of 100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil was mixed on a 1-liter Banbury-mixer over 5 minutes at 120 °C. 4.2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, BCI-C3 and an antioxidant were added to the rubber mixture on a two-roll mill (friction ratio 1:1.2) over 5 minutes at 40 °C. The results of the rheological measurements during vulcanization at 180 °C are listed in Table 8.

TABLE 8

Ex.no.	BCI-C3 (phr)	anti- oxidant (phr)	t _{s2} (min)	t ₉₀ (min)	ts ₂ /t ₉₀	Δtorque (N.m)
control	-----	---	1.1	9.0	0.12	9.8
19	1.1	BHT (1.8)	1.3	8.3	0.16	9.7
20	1.2	TQ (1.3)	1.3	8.9	0.15	9.7

t₉₀: vulcanization time

Δtorque: measure of crosslink density

The addition of a biscitraconimido compound and an antioxidant to rubber compositions gives a longer scorch time

without significantly changing the vulcanization time or the crosslink density.

Examples 21-22 and Comparative Example I

A rubber mixture of 100 parts EPDM, 50 phr carbon black and 10 phr paraffinic oil was mixed on a 1-liter Banbury-mixer over 5 minutes at 120 °C. 4.2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, a coagent and MBTS were added to the rubber mixture on a two-roll mill (friction ratio 1:1.2) over 5 minutes at 40 °C. The results of the rheological measurements during vulcanization at 180 °C are listed in Table 9.

TABLE 9

Ex.no.	coagent (phr)	MBTS (phr)	t_{s2} (min)	t_{90} (min)	t_{s2}/t_{90}	Δ torque (N.m)
control	-----	---	1.1	9.0	0.12	9.8
21	BCI-C3 (1.1)	0.65	1.5	8.1	0.17	8.9
22	BCI-C3 (2.2)	0.65	1.4	8.4	0.17	9.4
I	TAC (2.0)	0.65	2.0	11.4	0.18	6.5

t_{90} : vulcanization time

Δ torque: measure of crosslink density

The addition of a biscitraconimido compound and MBTS to rubber compositions does not significantly change the vulcanization time or the crosslink density in comparison with the combination of TAC and MBTS which shows a very low crosslink density together with a long vulcanization time in the rubber composition (Comparative Example I).

Example 23 and Comparative Example J

A rubber mixture was made of 100 parts EVA, 2 phr zinc oxide, 0.5 phr stearic acid and 2 phr azodicarbonamide as blowing agent in a Banbury mixer at 150 °C over 5 minutes. 2 phr of a 40% formulation of bis(tert-butylperoxyisopropyl)benzene, a coagent and TBHQ were added in a two roll mill (friction ratio 1:1.2) to the rubber mixture at 50 °C over 5 minutes, prior to vulcanization. The result was a white coloured foamed rubber.

The rheological measurements were made at a temperature of 170 °C with a Göttfert-elastograph (International Standard ISO 6502). The results are listed in Table 10.

TABLE 10

Ex.no.	TBHQ (phr)	coagent (phr)	t ₁₀ (min)	t ₉₀ (min)	t ₁₀ /t ₉₀
23	0.15	BCI-C2 (1)	2.3	10.6	0.22
J	0.15	HVA-2 (1)	1.1	10.8	0.1

t₁₀: Time wherein 10% of the rubber is crosslinked.
t₉₀: Time wherein 90% of the rubber is crosslinked.

The addition of the two coagents to a rubber composition before crosslinking gives a big improvement in scorch time as measured by t₁₀. Furthermore, the use of HVA-2 gives a colouring of the white foam during crosslinking in comparison with the use of BCI-C2.

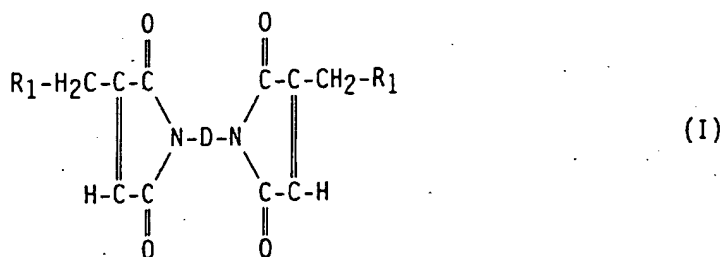
Claims

1. A peroxide-vulcanized rubber composition which comprises the vulcanization reaction product of:

(A) 100 parts of at least one natural or synthetic rubber;

(B) 0.04 to 10 parts by weight of an organic peroxide;

(C) 0.5 to 10 parts by weight of a bisimido compound represented by formula I:



wherein D is a divalent group chosen from the group of alkylene, alkarylene, cycloalkylene, arylene, aralkylene, and alkenylene, and R₁ is hydrogen or an alkyl group with 1-18 carbon atoms; and

(D) 0.1 to 10 parts by weight of a radical scavenger,

all amounts based on the weight of said rubber.

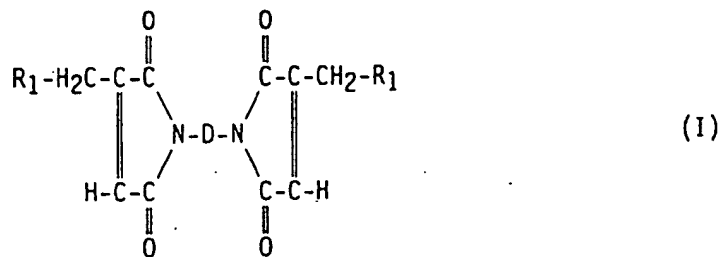
2. A peroxide-vulcanized rubber composition according to claim 1, wherein said radical scavenger is an antioxidant.

3. A peroxide-vulcanized rubber composition according to claim 2, wherein said antioxidant is a phenolic compound.

4. A peroxide-vulcanizable rubber composition according to claim 1, wherein the radical scavenger is a mercapto derivative.

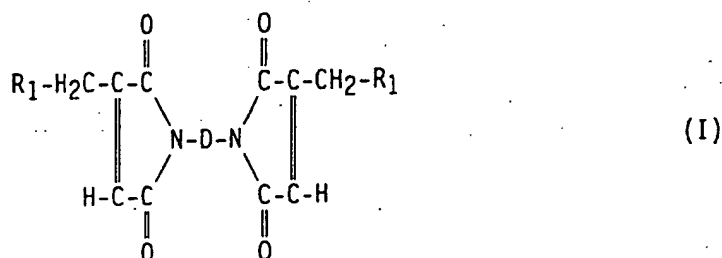
5. A process for the vulcanization of a vulcanizable rubber composition containing 100 parts of at least one natural or synthetic rubber with 0.04 to 10 parts by weight of an organic peroxide, comprising the step of vulcanizing said rubber at a temperature of from 80 to 300°C for a period of 30 seconds up to 10 hours to crosslink the rubber

composition, characterized in that said vulcanizable rubber composition further comprises 0.5 to 10 parts by weight of a bisimido compound represented by formula I:



wherein D is a divalent group chosen from the group of alkylene, alkarylene, cycloalkylene, arylene, aralkylene, and alkenylene, and R₁ is hydrogen or an alkyl group with 1-18 carbon atoms; and 0.1 to 10 parts by weight of a radical scavenger, all amounts based on the weight of said rubber.

6. A process in accordance with claim 5 wherein the vulcanization is carried out at 120-180°C for a period of 2 minutes up to 2 hours.
7. A process in accordance with claims 5 and 6 wherein the radical scavenger is an antioxidant.
8. A process in accordance with claim 7 wherein said antioxidant is a phenolic compound.
9. Use of a combination of a bisimido compound represented by formula I

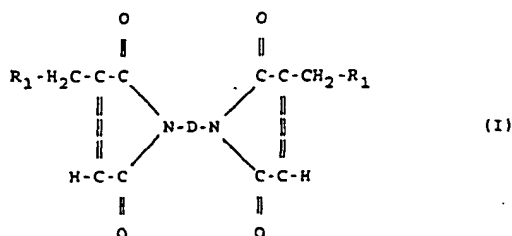


wherein D is a divalent group chosen from the group of alkylene, alkarylene, cycloalkylene, arylene, aralkylene, and alkenylene, and R₁ is hydrogen or an alkyl group with 1-18 carbon atoms; and a radical scavenger, to control scorch time in peroxide-cured rubber vulcanization.

Revendications

1. Une composition de caoutchouc vulcanisé au peroxyde qui comprend le produit de vulcanisation de:

- (A) 100 parties d'au moins un caoutchouc naturel ou synthétique;
- (B) 0,04 à 10 parties en poids d'un peroxyde organique;
- (C) 0,5 à 10 parties en poids d'un dérivé bis-imido répondant à la formule I:



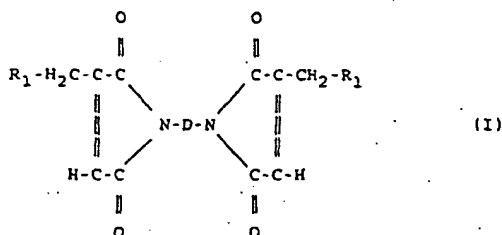
dans laquelle:

D est un groupe divalent choisi dans le groupe constitué par alkylène, alkarylène, cycloalkylène, arylène, aralk-

ylène et alkénylène; et

R_1 est un atome d'hydrogène ou un groupe alkyle comportant 1 à 18 atomes de carbone; et
(D) 0,1 à 10 parties en poids d'un piège à radicaux (scavenger),
toutes les quantités étant exprimées par rapport au poids dudit caoutchouc.

2. Une composition de caoutchouc vulcanisé au peroxyde selon la revendication 1, dans laquelle ledit piège à radicaux (scavenger) est un antioxydant.
3. Une composition de caoutchouc vulcanisé au peroxyde selon la revendication 2, dans laquelle ledit antioxydant est un dérivé phénolique.
4. Une composition de caoutchouc vulcanisé au peroxyde selon la revendication 1, dans laquelle ledit piège à radicaux (scavenger) est un dérivé mercapto.
5. Un procédé de vulcanisation d'une composition de caoutchouc vulcanisable contenant 100 parties d'au moins un caoutchouc naturel ou synthétique et 0,04 à 10 parties en poids d'un peroxyde organique, comprenant les étapes de vulcanisation dudit caoutchouc à une température de 80°C à 300°C pendant une période de 30 secondes à 10 heures, pour réticuler la composition de caoutchouc, caractérisé en ce que ladite composition de caoutchouc vulcanisable comprend en outre 0,5 à 10 parties en poids d'un dérivé bis-imido répondant à la formule I:

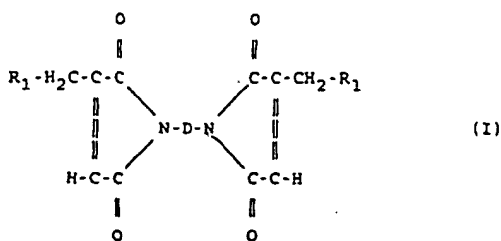


dans laquelle:

D est un groupe divalent choisi dans le groupe constitué par alkylène, alkarylène, cycloalkylène, arylène, aralkylène et alkénylène; et

R_1 est un atome d'hydrogène ou un groupe alkyle comportant 1 à 18 atomes de carbone; et
et 0,1 à 10 parties en poids d'un piège à radicaux (scavenger), toutes les quantités étant exprimées par rapport au poids dudit caoutchouc.

6. Un procédé selon la revendication 5, dans lequel la vulcanisation est mise en oeuvre à une température de 120°C à 180°C pendant une période de 2 minutes à 2 heures.
7. Un procédé selon la revendication 5 ou la revendication 6, dans lequel le piège à radicaux (scavenger) est un antioxydant.
8. Un procédé selon la revendication 7, dans lequel ledit antioxydant est un dérivé phénolique.
9. Utilisation d'une combinaison de dérivés bis-imido répondant à la formule I:



dans laquelle:

D est un groupe divalent choisi dans le groupe constitué par alkylène, alkarylène, cycloalkylène, arylène, aralkylène et alkénylène; et

R₁ est un atome d'hydrogène ou un groupe alkyle comportant 1 à 18 atomes de carbone; et

et un piège à radicaux (scavenger) pour contrôler le temps de "brûlage" lors de la vulcanisation de caoutchouc au peroxyde.

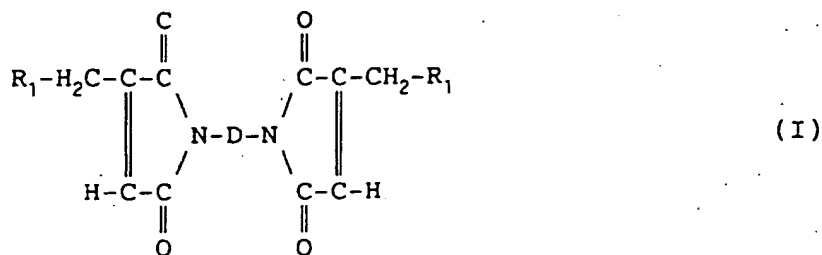
Patentansprüche

1. Peroxid-vulkanisierte Kautschukzusammensetzung, enthaltend das Vulkanisationsreaktionsprodukt von:

(A) 100 Teilen mindestens eines natürlichen oder synthetischen Kautschuks;

(B) 0.04 bis 10 Gewichtsteilen eines organischen Peroxids;

(C) 0.5 bis 10 Gewichtsteilen einer Bisimidoverbindung gemäss der Formel I:



worin D eine divalente Gruppe, gewählt aus der Gruppe Alkylen, Alkarylen, Cycloalkylen, Arylen, Aralkylen und Alkenylen, ist und R₁ Wasserstoff oder eine Alkylgruppe mit 1 - 18 Kohlenstoffatomen bedeutet; und

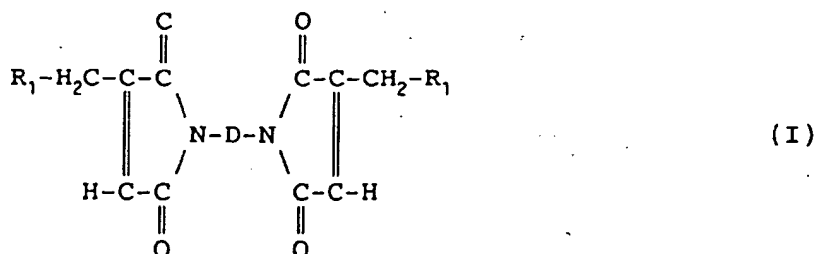
(D) 0.1 bis 10 Gewichtsteilen eines Abfangmittels für Radikale, wobei alle Anteile auf das Gewicht des Kautschuks bezogen sind.

2. Peroxid-vulkanisierte Kautschukzusammensetzung gemäss Anspruch 1, bei der das Abfangmittel für Radikale ein Antioxidationsmittel ist.

3. Peroxid-vulkanisierte Kautschukzusammensetzung nach Anspruch 2, bei der das Antioxidationsmittel eine phenolische Verbindung ist.

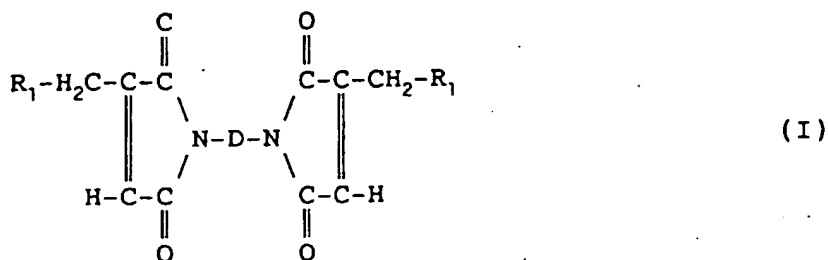
4. Mit Peroxid vulkanisierbare Kautschukzusammensetzung nach Anspruch 1, bei der das Abfangmittel für Radikale ein Mercaptoderivat ist.

5. Verfahren zur Vulkanisation einer vulkanisierbaren Kautschukzusammensetzung, die 100 Teile mindestens eines natürlichen oder künstlichen Kautschuks und 0.04 bis 10 Gewichtsteile eines organischen Peroxids enthält, durch Vulkanisieren des Kautschuks bei einer Temperatur von 80 bis 300°C während eines Zeitraums von 30 Sekunden bis 10 Stunden zur Vernetzung der Kautschukzusammensetzung, dadurch gekennzeichnet, dass die vulkanisierbare Kautschukzusammensetzung ausserdem 0.5 bis 10 Gewichtsteile einer Bisimidoverbindung entsprechend der Formel I:



in der D eine divalente Gruppe, gewählt aus der Gruppe von Alkylen, Alkarylen, Cycloalkylen, Arylen, Aralkylen und Alkenylen, ist und R₁ Wasserstoff oder eine Alkylgruppe mit 1 - 18 Kohlenstoffatomen bedeutet, und 0.1 bis 10 Gewichtsteile eines Abfangmittels für Radikale enthält, wobei alle Anteile auf das Gewicht des Kautschuks bezogen sind.

6. Verfahren nach Anspruch 5, bei welchem die Vulkanisation bei 120 - 180°C während eines Zeitraums von 2 Minuten bis zu 2 Stunden durchgeführt wird.
7. Verfahren nach den Ansprüchen 5 und 6, bei welchem das Abfangmittel für Radikale ein Antioxidationsmittel ist.
8. Verfahren nach Anspruch 7, bei welchem das Antioxidationsmittel eine phenolische Verbindung ist.
9. Verwendung einer Kombination einer Bisimidoverbindung entsprechend der Formel I



in der D eine zweiwertige Gruppe, gewählt aus der Gruppe Alkylen, Alkarylen, Cycloalkylen, Arylen, Aralkylen und Alkenylen, ist und R₁ Wasserstoff oder eine Alkylgruppe mit 1 - 18 Kohlenstoffatomen bedeutet, mit einem Abfangmittel für Radikale zur Steuerung der Anvulkainsationsdauer bei der Kautschukvulkanisation mit Peroxidvernetzung.